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Application of bamboo charcoal used as biochar on ecological environment

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Abstract

Bamboo grows rapid and four-year-old bamboo can be used as raw material to produce many products. Bamboo has strong reproductive ability. The more mature bamboos are cut down, the more favorable it is for the germination of new bamboo shoots and the improvement of bamboo quality. It can also create healthy bamboo forests and improve the benefits of national security. Bamboo forests are widely distributed all over the world and are known as "the second largest forest in the world". The bamboo industry developed through the utilization of bamboo resources has become a globally recognized green industry with huge economic, ecological and cultural values. Bamboo used as the non-wooden resources have become a strategic natural resource. The advantages of bamboo resources can improve livelihoods and eliminate poverty, create a safe, resilient and sustainable living environment. Therefore, bamboo become a green material with great potential for development. Through carbonization technology, mature bamboo is transformed into bamboo charcoal, which is a porous material used as biochar for environmental soil improvement. At the same time, the bamboo vinegar produced in the production process can be used as a material for pest control. In order to allow small rural areas to produce bamboo charcoal and bamboo vinegar by themselves, an energy-saving and rapid carbonization furnace was developed, and through program control technology, labor costs were greatly reduced. Using bamboo charcoal and bamboo vinegar as organic planting materials through composite material technology can increase crop harvest by at least 10%. Taking organic soybeans as an example, it can increase harvest by about 30%. It effectively prevents and control pests and diseases, and reduce chemical fertilizers and the use of pesticides achieves. It will build an eco-friendly environment.

Keywords Bamboo; Biochar; Vinegar; Eco-friendly

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1. Introduction

The Taiwan Luoshan Recreation Area is located in Luoshan Village, Fuli Township, a small village located beside the coastal mountains. Hakka people are the main residents, comprising about 80%, and the remaining 20% are Hoklo Taiwanese and Plain Indigenous People (平埔族). Luoshan Village is located between the central mountains and coastal mountains, squeezed in between the Eurasian plate and the Philippine plate, which is commonly known as the Huadong Vertical Valley. The geographical environment therefore changes and the natural landscape resources are rich. There are diverse landscapes such as high mountains, hills, terraces, flowing water, waterfalls, fault pools (Luoshan Fish Pound), and hot springs. Special geological landscapes such as this, which include mud volcanoes and evil lands formed by post-volcanic activities, are rare and precious geographical wonders in Taiwan. It also belongs to the igneous rock soil system of the coastal mountains, with excellent, fertile soil. In addition, Luoshan Waterfall is upstream of Luozai River, which runs down the west side of the eastern coastal mountains. The water is pure and sweet, and it is an important water source for the livelihood and farmland irrigation of the residents of Luoshan Village. However, the temperature of the hot spring in the Nasan area, which is mixed with mineral water from the central mountains, is only around 35°C. If local natural resources can heat it up, tourists will flock to the region.

According to the results of the fourth forest survey in Taiwan, and statistics of the forest coverage area of each county and city, Hualien County has the largest forest area of 373,000 hectares, followed by Nantou County with 303,000 hectares. The forest coverage rate of Taitung County was the highest at 81.64%, followed by Hualien County at 80.54%. The forest resources of Hualien County contain about 7,800 hectares of bamboo, most of which are mainly distributed by Makino Bamboo. Among the six economic bamboo species, the majority is used, accounting for more than 90% of coverage. Most of them are used as agricultural pillars, but can also be used as raw materials for bamboo crafts. Luoshan Village also has many cinnamon bamboo forests, but effective management has been lacking for a long time. As a result, the diameter of cinnamon bamboo is less than 5 cm, and some are only 2-3 cm, which is difficult to use. To promote the recovery of local Makino Bamboo forests and effectively reuse and increase the economic benefits of the forest (bamboo shoots), it is necessary to cut down over three-year-old bamboo to allow Makino Bamboo to grow more vigorously. A lot of bamboo resources will be produced in the thinning process, which can be considered the local reuse of natural resources.

Bamboo can be made into bamboo charcoal (biochar) by carbonization, and biochar is the solid product obtained by the pyrolysis process using wood materials (wood, bamboo, etc.) in an anoxic environment. During this process, the smoke can be condensed to obtain a by-product vinegar. Biochar and vinegar can promote soil activation, prevent pests and diseases, increase crop productivity, and make plant flowers and leaves more colorful and durable (Liu 2010; Yeh 1998; Hseuh 2000). Lin et al (2010, 2011) and Ho et al (2013) improved plant growth and yield by mixing bamboo charcoal into soil due to its large specific surface area, good water retention, water permeability, and fertility. Due to its porosity, biochar can promote the growth of microbiota, which helps decompose organic matter in the soil, thus reducing the acidity of soil and providing a suitable environment for plants to grow (Kothamasi et al. 2006). Furthermore, Lin et al (2014) demonstrated that the carbon material had no cytotoxicity and mutagenicity through an An's test, so it can be regarded as a natural material with preliminary safety.

To create a sustainable green cycle of mountain villages with local characteristics, and provided that felled bamboo forest resources are properly used, reuse unit micro-equipment of forestry green materials can be built, and local farmers developed into technical seed personnel, combining forestry, agriculture, and tourism, to create a friendly ecological environment and local eco-tourism area, and provide employment opportunities for young people in rural communities to return to their hometowns to revitalize the rural economy and resource recycling. Furthermore, to effectively improve the logging efficiency of bamboo vinegar during the carbonization process of bamboo, it is necessary to convert heat energy and collect more bamboo vinegar by heat exchange condensation through water cooling systems, also ensuring warm water is produced for use.

In this research, bamboo pre-treatment equipment is planned for construction by reusing the natural resources felled in Luoshan Village; biochar and bamboo vinegar are prepared through the carbonization process to prepare soil amendments and natural agent of pests and diseases for organic crops. Through a high-efficiency heat exchange system, the water temperature of the hot spring is raised to more than 40°C. In the future, it can be combined with the construction of regional light viewing hardware as a leisure and sightseeing resource, combining farmers' production and environmental ecology, and implementing the Satoyama Initiative.

2. Material and Method

2.1. Select sites for bamboo felling and calculate volumes

In an effort to understand the amount of bamboo wood that can be collected by per unit area of the bamboo forest in Luoshan Village, five forest lands were selected for thinning (Figure **4**-Figure **7**), and areas of mud volcano sections Nos. 1184, 1481, 1296, 1506, and 1507 were felled respectively, with a total bamboo forest area of about 1.9 hectares.

2.2. Equipment

This research adopts a rapid energy-saving carbonization furnace, including two sets of batch carbonization furnaces, which can be alternatively operated every day (the amount of flake and granular bamboo in each batch is more than 300 kg, carbonization heating time is less than 8-10 hours, and carbon yield is more than 20%), and one high-efficiency condensing heat exchange system (the water supply is about 0.5 metric tons per hour, and the temperature of hot spring water can be raised to more than 60°C. The mixed hot spring raw water can supply one metric ton of hot spring water above 40-45°C per hour, which can be used in the foot bath experience pool), and can collect bamboo vinegar by condensation, with a logging rate of more than 25%. It also contains a set of exhaust environmental protection treatment systems to avoid smoke spills and dispersion, as shown in **Error! Reference source not found.** The production procedure is to collect, pulverize, and dry the bamboo, and then feed the material from the above entrance of the carbonization furnace through the feeding equipment. After completing the above steps, firing, carbonizing, and cooling processes complete overall carbonization. The whole carbonization process (Figure **3**) is quite convenient, and all operation parameters are set through a man-machine interface to control the temperature in the carbonization furnace and the unit control switch, all of which are automated to reduce labor costs.

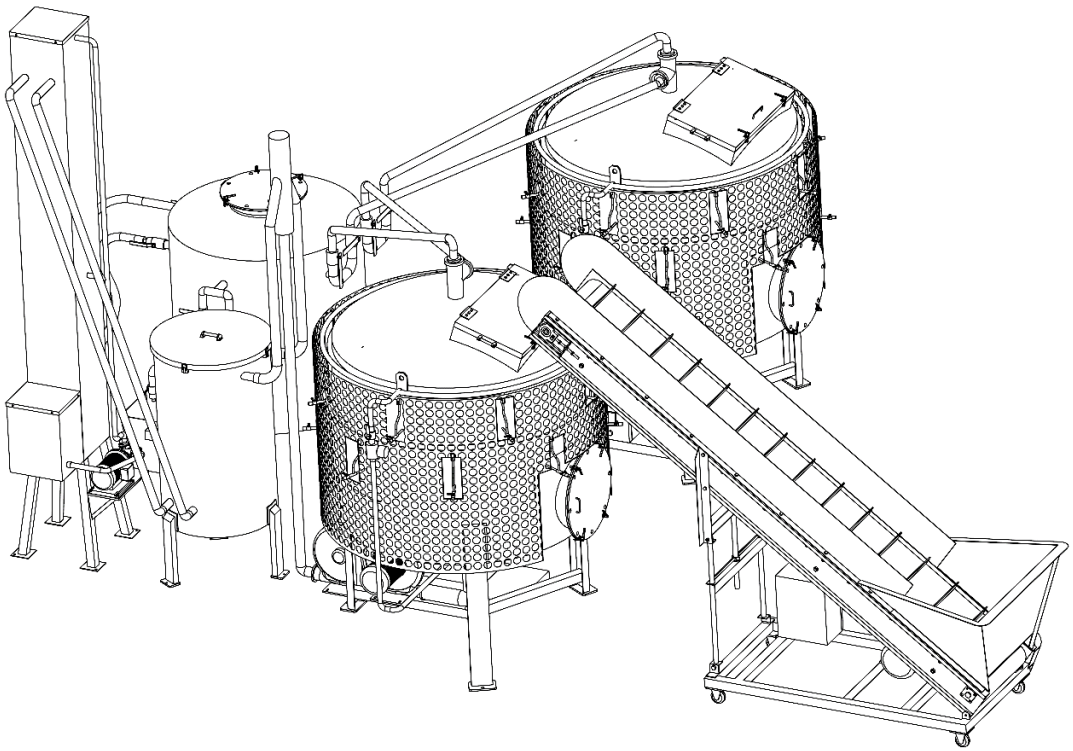

Figure 1. 3D design of rapid and energy-saving carbonization furnace.

Figure 2. Rapid energy-saving carbonization furnace system.

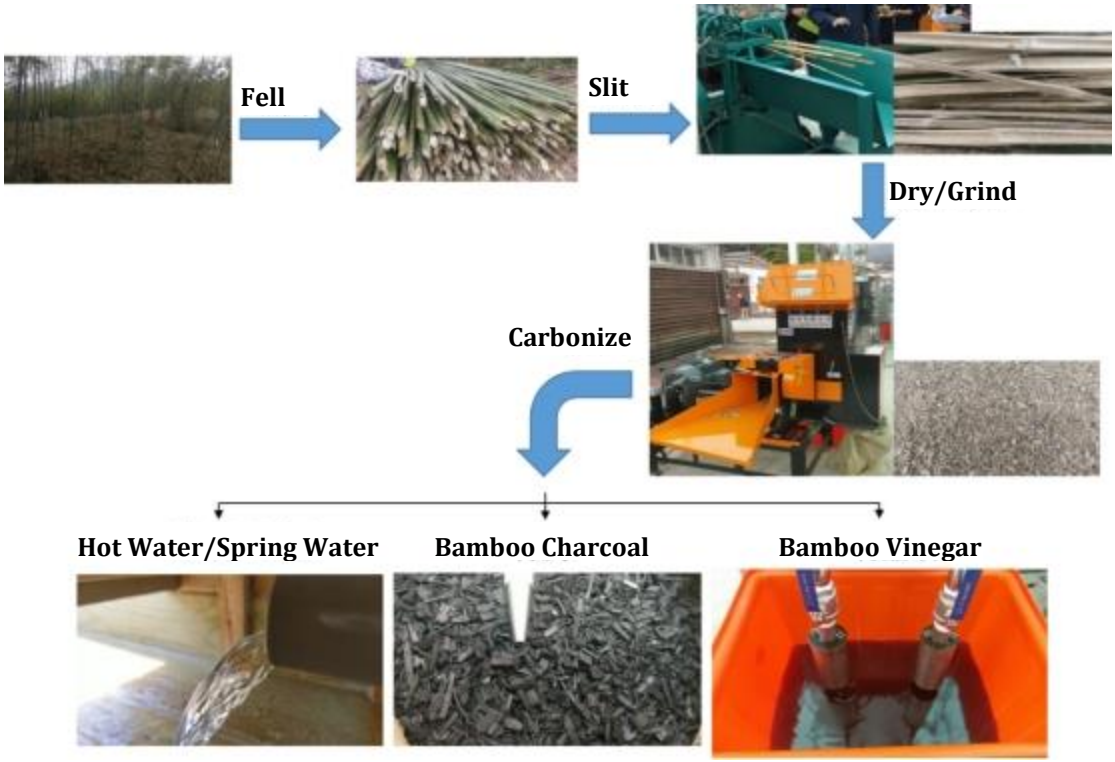

Figure 3. Flow chart of bamboo charcoal production in a rapid energy-saving carbonization furnace.

3. Results and Discussion

3.1. Evaluation of bamboo forest logging

As there are many bamboo forest in the Luoshan area that have been neglected for a long time, and and Makino Bamboo s are selectively cut on a three-year rotation to avoid cutting them while they are too tender, but, if left uncut for a long time, bamboo forests can also age and die, a bamboo forest should be regularly thinned to create a virtuous cycle of growth, thus obtaining good quality bamboo and collecting Makino Bamboo shoots. However, at present, the utilization rate of bamboo in the east is very low, and the sale price has plummeted so much that landlords are reluctant to cut down and sell it, leaving the forests without being tended to. Through this research, resources can be recycled, hot spring water generated, bamboo charcoal made, and more, adding utilization value. The actual area of bamboo forest felled is 1.3 hectares and a total of 15.2 metric tons of bamboo was obtained for this research; an average of 11.6 metric tons of bamboo can be obtained from one hectare of bamboo forest (Figure 4-Figure 7). In addition, the stronger the vitality of bamboo forest land through management, the more bamboo can be collected; bamboo forests can be used to produce biochar and vinegar through rapid

energy-saving carbonization furnaces, as soil amendments and biological agents, and as pest control, so local bamboo forests can be sustainably recycled and the Satoyama Initiative can be implemented in Luoshan Village

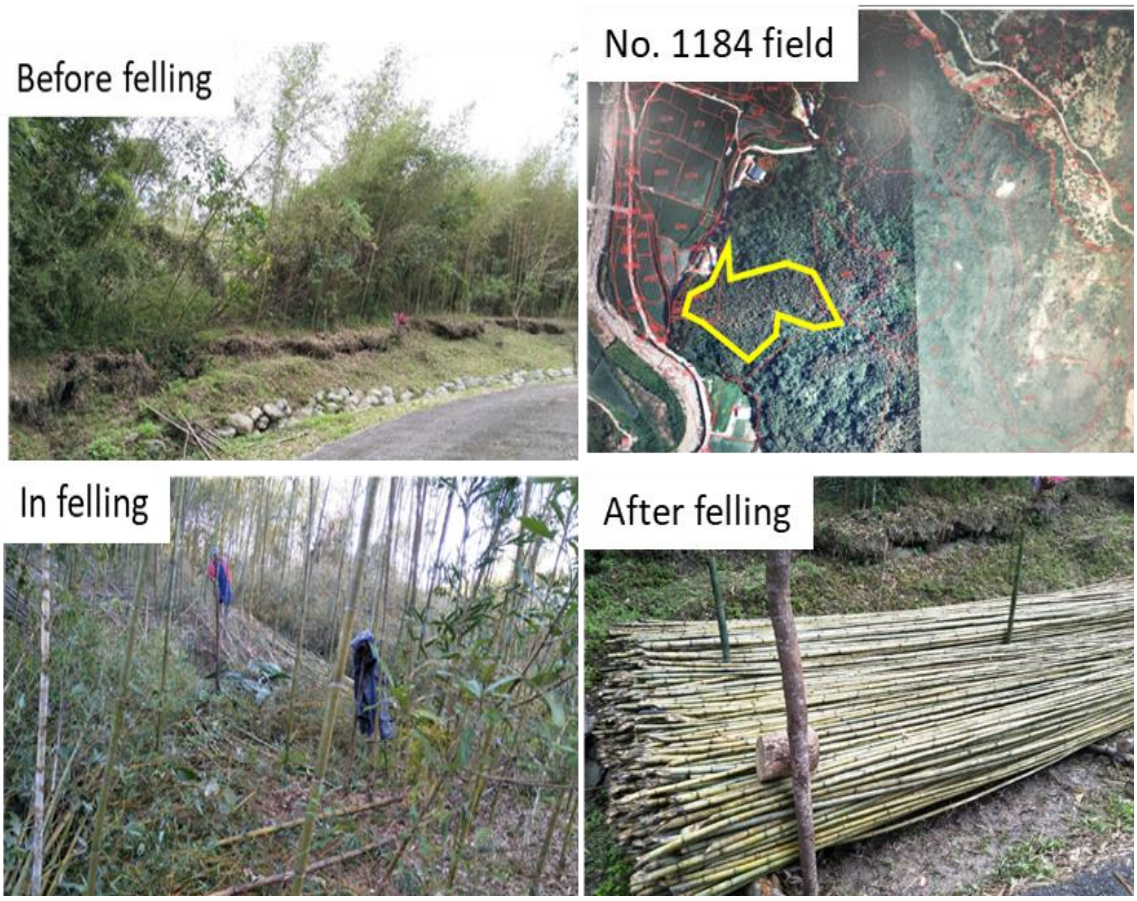

Figure 4. Bamboo Forest in Mud Volcano Section No. 1184.

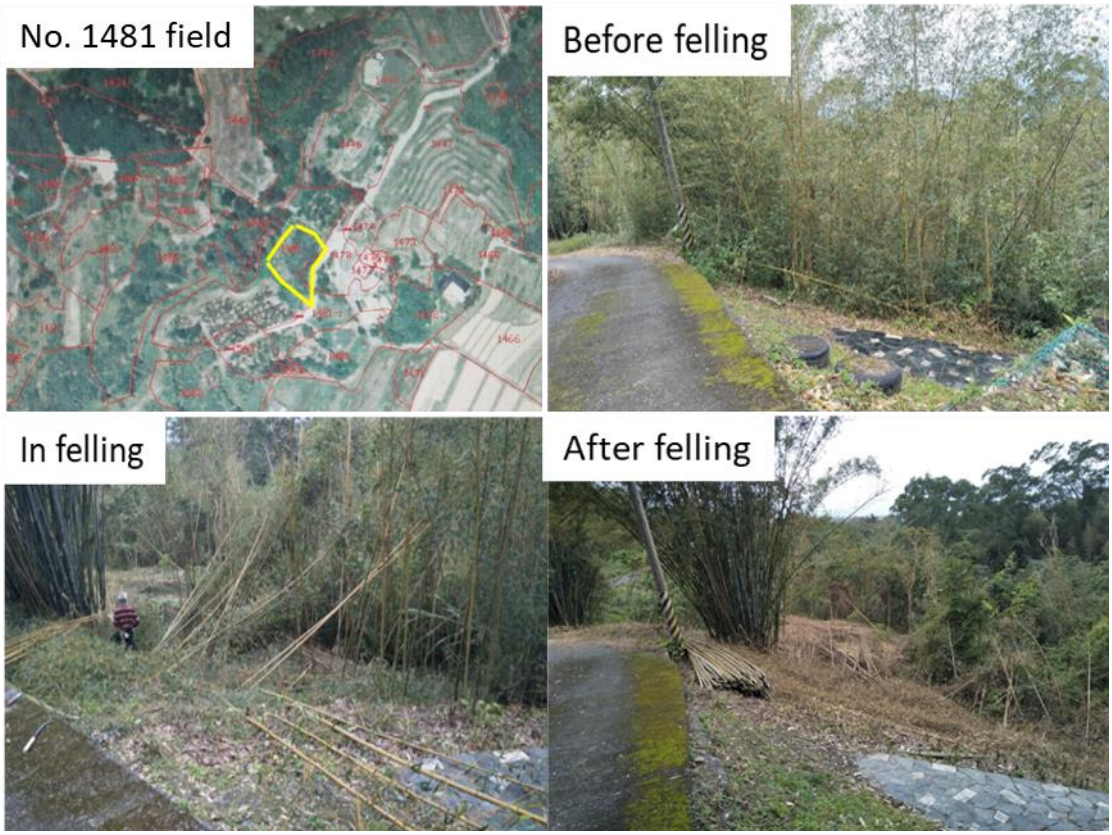

Figure 5. Bamboo Forest in Mud Volcano Section No. 1481

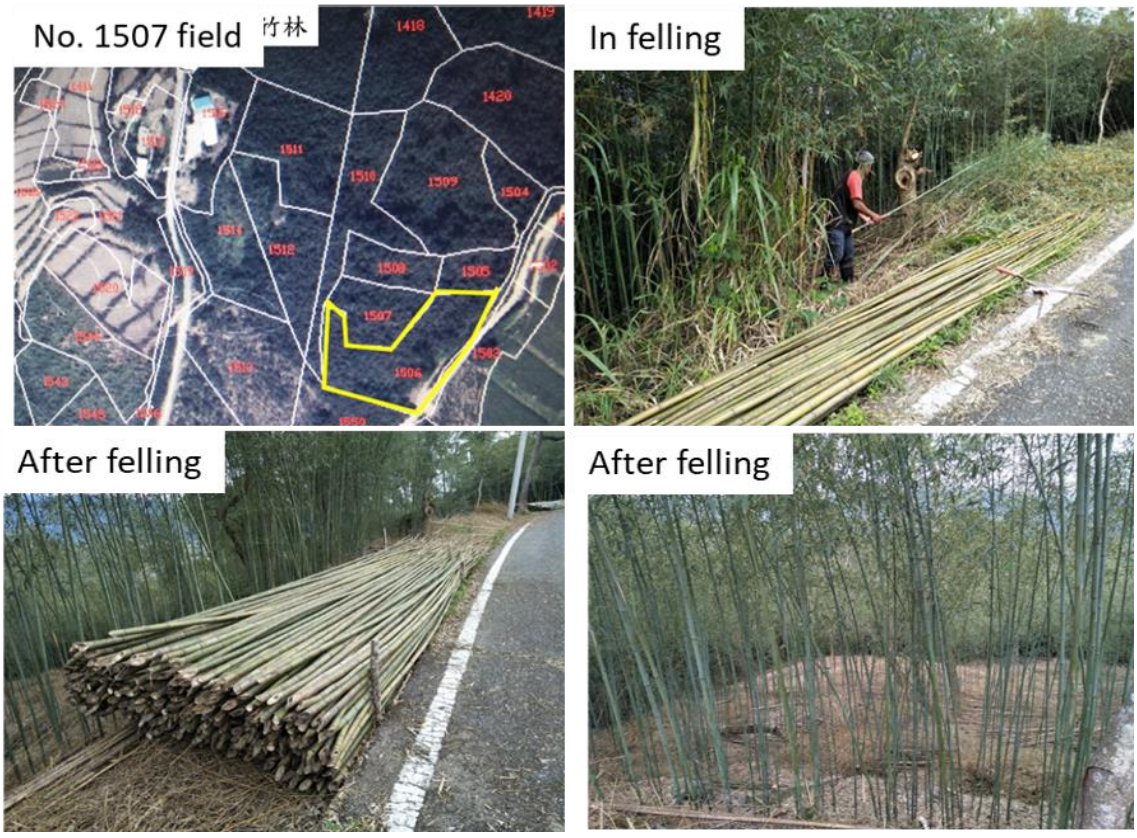

Figure 6. Bamboo Forest in Mud Volcano Section No. 1506/1507.

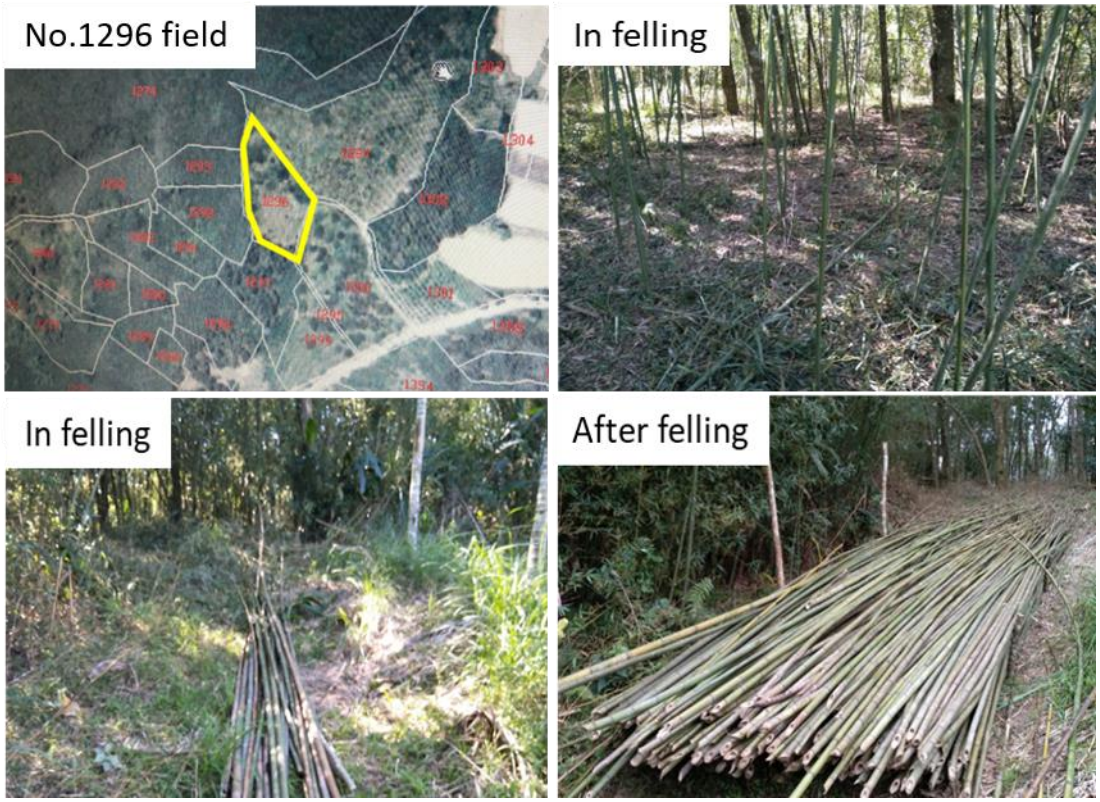

Figure 7. Bamboo Forest in Mud Volcano Section No. 1296.

2. Energy-saving and rapid carbonization furnace test

By placing bamboo with less than 12% moisture content in a rapid energy-saving carbonization furnace, about 25% bamboo charcoal (75 kg) and 35% bamboo vinegar (105 liters) can be obtained (Figure 8). Fixed carbon of bamboo charcoal is 83.7%, carbon content is 79.9%, hydrogen content is 2.80%, oxygen content is 10.1%, nitrogen content is 0.61%, sulfur content is 0.31%, pH value is 9.43, organic matter is about 10.3%, total nitrogen is 0.61%, total phosphorus anhydride is 0.24%, and total potassium oxide is 1.66%. Bamboo vinegar fluid pH is 2.89, and by GC/MS analysis, deducting the moisture with diethyl ether extraction, we learned that the acid content is about 50.59%, with about 23.56% phenolic ingredients, and 24.83% other ingredients. In the carbonization process, the central hot spring water is heated to 40°C and is used by tourists as a foot bath (Figure Figure **9**).

From the above analysis, we can see that bamboo charcoal is an alkaline porous material, which can be used to optimize acid soil, increase soil permeability, and retain water and fertilizer. Furthermore, the main components of bamboo vinegar are acidic substances, mainly acetic acid, and phenolic substances, which can also be used as organic materials for disease and insect control.

Figure 8. Bamboo charcoal and vinegar.

Figure 9. Foot soaking experience field from rapid carbonization furnace heating hot spring water.

3. Field application test of biochar and vinegar

Bamboo can be utilized through carbonization equipment and a heat exchange system, and bamboo charcoal (biochar) and vinegar can be obtained at the same time as organic material. In this project, biochar is used to improve the soil and crop growing environment, and bamboo vinegar is used to promote crop growth (planting record), and for pest control test and management. For soybeans and red beans, the experimental group (adding 300 kg of bamboo charcoal per plot) and the control group each have one plot (

Figure **10**). The tillage procedures include soil turning, seeding, weeding, and spraying biological agent. The soil test demonstrated pH = 6.3, organic matter = 2.0%, phosphorus = 13ppm, potassium = 47ppm, calcium = 1,511ppm, and magnesium = 398ppm.

Figure 10. Crop demonstration area management and planting records.

By measuring above-ground plant height, and leaf length and width, it was found that the experimental group that had bamboo charcoal applied was significantly better than the control group (Figure

Figure 11), indicating that bamboo charcoal was effective in soil improvement. In addition, the preparation of biological agents with bamboo charcoal and bamboo vinegar, diluted 200 times and sprayed on crop leaves, can effectively control the occurrence of diseases and pests. According to the harvest data (Figure Figure **12**), the number of pods per plant with improved soil was higher than that of the control group, and the average weight of soybeans and red beans harvested was greater. The total number of pods per 10 soybeans increased from 366 to 396 (Figure Figure **13**), and the total weight of 50 soybeans was 831 grams in the control group and 1,081 grams in the experimental group. The 1000-grain weight was 280 kg in the control group and 292 kg in the experimental group. The results showed an increasing yield by about 10-30%. As the harvest of red beans coincided with heavy rain, many of the beans decomposed, and 2,500 red beans were weighed (Figure 14. The weight of 2,000 red beans.

) as 215 kg in the control group and 231 kg in the experimental group, which increased the harvest by 7%. It can therefore be determined that bamboo charcoal and bamboo vinegar can be applied to organic soybean cultivation to optimize soil, for pest control, to promote crop growth, and increase the overall harvest.

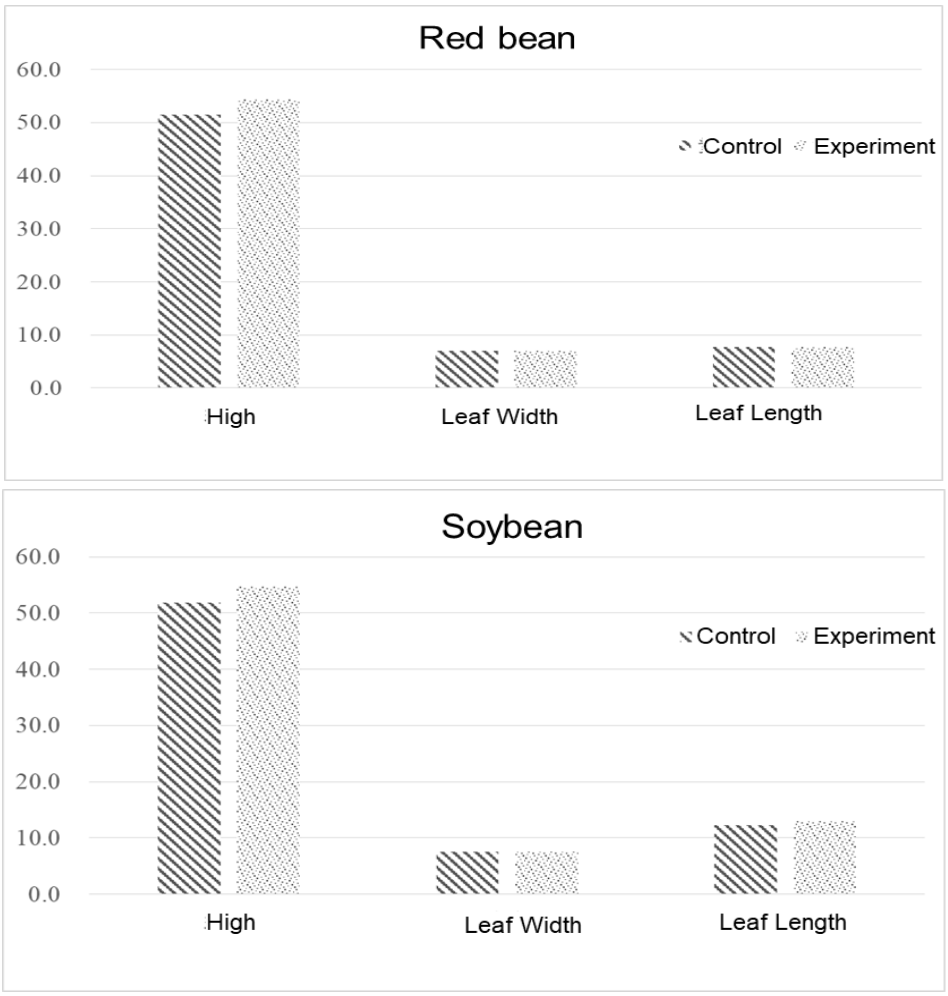

Figure 11. Soybean and red bean planting records, plant height, leaf width and length

Figure 12. Red bean and soybean appearance.

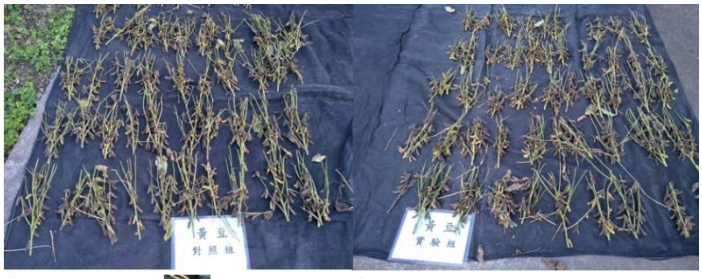

Figure 13. Number of pods, 50 plants and 1000-grain weight of soybeans.

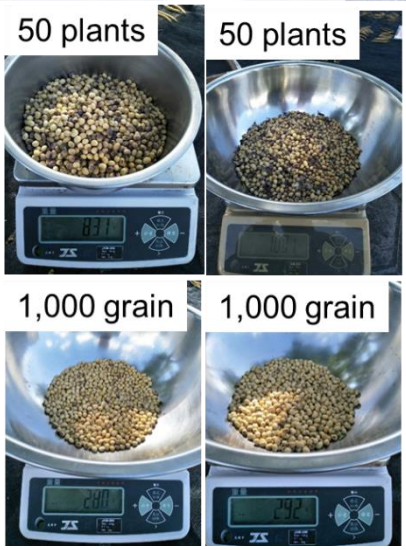

Figure 14. The weight of 2,000 red beans.

Conclusion

Proper management and thinning of bamboo forest are conducive to the growth of bamboo. In addition, it can be utilized as biomass material to produce biochar and bamboo vinegar through the carbonization and heat exchange system. They can be used as agricultural materials, which can promote crop growth and pest control. Actually, bamboo biochar and vinegar have been used as crops in Luoshan Organic Village. According to the results, it can increase the harvest yield by 10-30%. Further, the hot spring water can also be heated to more than 60°C by the excess heat of the carbonization and mixed with raw water to maintain a temperature of about 40-45°C for hot spring experience use. With the recycling of land resources and combination of tourism resources, the Satoyama Initiative can be implemented to boost the economic development of Luoshan Village.

Conflict of Interest

The authors declare there is no conflict of interest

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